DOCUMENT RESUME

ED 180 917 SO 012 298

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TITLE Education for the '80's - And Beyond the Socio-Scientific Reasoning Model.
PUB DATE Nov 79
NOTE 23p.

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Behavioral Science Research; Cognitive Development; Curriculum Development; Decision Making; Educational Philosophy; Educational Research; *Educational Theories; Ethical Values; *Futures (of Society); Higher Education; Literature Reviews; Models; *Moral Development; Moral Values; Problem Solving; *Productive Thinking; *Psychology; Sciences; Secondary Education; Theories
IDENTIFIERS Kohlberg (Lawrence); Piaget (Jean); Selman (Robert)

ABSTRACT

Research and theories by psychologists Jean Piaget, Lawrence Kohlberg, and Robert Selman on problem solving, decision making, moral development, and critical-thinking skills are reviewed. These theories and research are combined with the author's theories to develop an original decision-making model, namely, the socio-scientific model. The model incorporates problem solving with the social and moral/ethical concerns of decision making. The major objective of the model is to aid educators as they develop educational materials which lead students to higher levels of thinking and reasoning. The basic assumption of this model is that effective problem solving for the future requires simultaneous development in the realms of logical reasoning, social role taking, and moral/ethical reasoning. To apply the model, educators must identify learning experiences appropriate for students at different grade levels, with differing abilities and needs. Activities are suggested for various stages of the model including classroom dilemma discussion, critical analysis, and evaluation of data. The conclusion is that the socio-scientific model is a good way to encourage productive decision making with regard to probable future conflicts. (DB)

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EDUCATION FOR THE '80's - AND BEYOND

THE SOCIO-SCIENTIFIC REASONING MODEL

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November 1979

SP 012 298

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EDUCATION FOR THE 80'S - AND BEYOND

THE SOCIO-SCIENTIFIC REASONING MODEL

I. Introduction

That we live in a highly scientific and technological world can hardly be disputed. Few would deny that society has, especially during the past century, come to rely on the achievements of science to make life more comfortable, convenient, and for many, more enjoyable. Few would deny that society is becoming increasingly more dependent upon the ingenuity and achievements of the scientific/technological world.

While no one can, with any degree of certainty, predict what future demands society will place on science, or, for that matter, what demands science will place on society, some things seem clear. First, we and those generations who follow us will continue to rely on science and technology to maintain and, more than likely, improve the quality of life for all. Furthermore, advances in science and technology will continue at such an accelerated pace that children growing up today and those yet to be born will live in a world whose leaders will possess awesome power. Unfortunately, the potential for conflict among the scientific, technological, and social sectors will, as time goes on, also increase as future decision-makers at several levels begin to use--or misuse--that power. Clearly, decision-makers that we are cultivating today will be required to solve problems and resolve conflicts which we encounter only in our wildest dreams, or, in some cases, only in our most frightening nightmares.

We are already beginning to see emerging the types of questions which will become common in the not very distant future.

- When individuals require new hearts and organs after their own have failed, the question will not be <u>can we</u> replace the defective organs, but rather, <u>should we</u>?

Note: Many of the ideas expressed in this paper were developed by the author in cooperation with Janey Cheu, Associate Director, Institute for Science, Technology, Social Science Education, Rutgers - The State University of New Jersey.

- The question will not be <u>can we</u> colonize outer space or the ocean depths to relieve the pressures of overpopulation, but rather, <u>should we</u>?
- The question will not be <u>can we</u> modify weather, climate, and other aspects of our environment, but rather, <u>should we</u>?
- The question will not be <u>can we</u> utilize the power of nuclear fusion to provide an almost limitless supply of energy despite its dangers, but rather, <u>should we</u>?
- The question simply will not be <u>can we</u> produce a "Brave New World" but rather, <u>should we</u>?

In brief, questions which today ask "can we" are being transformed rapidly into the more appropriate "should we"?

Science and technology are able to deal effectively with issues of the "can we" variety, for these are decided by scientists and engineers on basic technical fact. Questions of the "should we" type require, on the other hand, the inclusion and consideration of another dimension--a values dimension. These values-based questions must, I maintain, be answered by society--people who are knowledgeable about the capabilities of science and technology--and their impacts and implications regarding such issues as justice, equity, and obligations, life, laws, individual rights, and so on.

How will future society respond to questions such as these? What should be the role of education? How should we prepare the leaders of tomorrow to deal with such awesome decision-making responsibility? How should we prepare our youth to make effective--yet equitable and just decisions--and to act responsibly and in the best interests of all?

In view of the accelerating rate of change and the rapid growth and accumulation of knowledge in nearly all fields of endeavor, reliance on

traditional programs of instruction and teaching methodologies which emphasize, for the most part, facts and information transfer is, in reality, teaching for obsolescence. To deceive ourselves into thinking that the "typical" secondary school student of today will tomorrow need to know the Periodic Table of the Elements by memory is pure folly. To implement, as some have proposed, a program of instruction which emphasizes the so-called "basic skills" to the near exclusion of all else--especially how to use or apply those basic skills--is at best naive.

In contrast, we must develop in our youth skills that are generalizable, highly flexible, and enduring; we must emphasize the development of what I consider to be skills which are at least as basic as any of those proposed to date. These basic skills, I submit, are problem solving, decision-making, and a variety of analytical and critical thinking skills. Moreover, in developing these skills a moral/ethical dimension must be included if today's students are going to effectively--humanely--deal with tomorrow's problems.

II. Theoretical Rationale

Hence, we at the Institute for Science, Technology, and Social Science Education at Rutgers - the State University, view education as development of those skills necessary for complex problem solving and decision-making. Moreoever, because the values component is inherent in all decision-making and results have such ramifications, and because of our continuing reliance upon the achievements of science and technology, such skill development should simultaneously emphasize moral/ethical concerns and focus on issues cast in a scientific, technological, social context.

The goals of development, we believe, should contain the following components:

- Increased logical reasoning skills in dealing with problems containing multiple interacting variables.
- Increased decision-making/problem solving skills incorporating socio-moral values considerations and a wider societal perspective.
- Increased knowledge of the broad issues emerging and projected at the interfaces of science/technology/society.

The question, then, is how to best approach the development of such complex and comprehensive problem-solving capabilities. Research in the general area of cognitive development and the specific areas of logical reasoning, social role-taking, and moral/ethical reasoning, provide clues and initial guidance in such endeavors. Those findings pertinent to our work are, in a condensed and highly simplified form, described.

Logical Reasoning

Jean Piaget, the noted Swiss psychologist, has made several important contributions in the area of cognitive development which are pertinent to our efforts (Piaget, 1970), (Gruber and Voneche, 1977). Piaget views the development of logical reasoning as progression through the series of stepwise stages indicated in Table 1 (sensori-motor, preoperational, concrete operational and formal operational). At each successive stage the logical reasoning ability of individuals takes on a broader perspective and incorporates the ability to deal with greater numbers of interacting variables of increasing intellectual complexity. Each stage of thinking builds upon the previous one, but takes on a new structural form. Growth in cognition, it seems, can be facilitated and nurtured through appropriate educational experiences.

TABLE 1

PIAGET'S STAGES OF COGNITIVE DEVELOPMENT

MORE ADEQUATE

FORMAL STAGE

FORMAL LOGICAL OPERATIONS
- Thinks in a hypothetical-deductive manner
- Considers all possible relationships

TRANSITIONAL - EARLY FORMAL OPERATIONS
- Begins to think more abstractly
- Awareness of new possibilities

CONCRETE STAGE

CONCRETE OPERATIONAL (SUBSTAGE 2)
- Reasons only about concrete objects
- Applies logic in a limited way

PRE-OPERATIONAL - (SUBSTAGE 1)
- Can represent objects symbolically - uses language, images
- View of world only as he/she sees it - highly egocentric

SENSORIMOTOR STAGE
- Acquires concept that objects exist apart from self
- Coordinates movement, habit

In explaining growth in logical reasoning capability, Piaget refers to the processes of assimilation, accommodation, and equilibration. Assimilation occurs when the child incorporates new ideas and situations into his or her existing thought structures. On the other hand, the child also encounters objects and events that do not fit into his or her existing thought structures. In these contradictory situations, the child has essentially two options: he/she must either enlarge his/her existing structures or create a new category or structure. Piaget defines this as the process of accommodation.

Intellectual growth, Piaget postulates, occurs when the individual attempts to resolve the tension between the interactive processes of assimilation and accommodation by developing new thoughts and responses that are more suitable or adequate. Equilibrium is re-established when thought structures are altered, producing new accommodations that enable the individual to assimilate the new situations. Intellectual growth, then, occurs through internal self-regulation processes that lead to new, higher levels of equilibration.

Moral/Ethical Reasoning

While there are several approaches to values education, the more encompassing one is the cognitive developmental approach offered by Lawrence Kohlberg (1976), (Gibbs, et al, 1976). Kohlberg's ideas are derived from the philosophic positions of Dewey and Piaget. The emphasis here is to help individuals grow intellectually and morally. This is, we feel, a more functional approach than arbitrary indoctrination of values as used in "character" or "socialization" education or taking a "values relativity" stance, typically employed in the more common values clarification approach.

Kohlberg's moral/ethical development theory is an extension of Piaget's

cognitive development theory. Similarly to Piaget, Kohlberg views moral development from childhood to adulthood as progression through a series of stages (Table 2). Each stage is characterized by a very different way of perceiving and interpreting one's experiences. At Kohlberg's Stage 2, for example, "right" and "wrong" are judged in terms of satisfying one's own needs and sometimes the needs of others if it is convenient to do so. At the higher principled stages, reasoning takes into account concerns for the welfare of others in a broader context, and includes concerns for human dignity, liberty, justice, and equality--those very same principles upon which our Constitution is based.

Following Piaget, Kohlberg views development not as mere accumulation of information, but changes in thinking capabilities--the structures of thought processes. In the course of development, higher-level thought structures are attained and result in the extension of an individual's social perspective and reasoning capabilities. Applying higher levels of thinking to problems results in problem solutions that have greater consistency and are more generalizable.

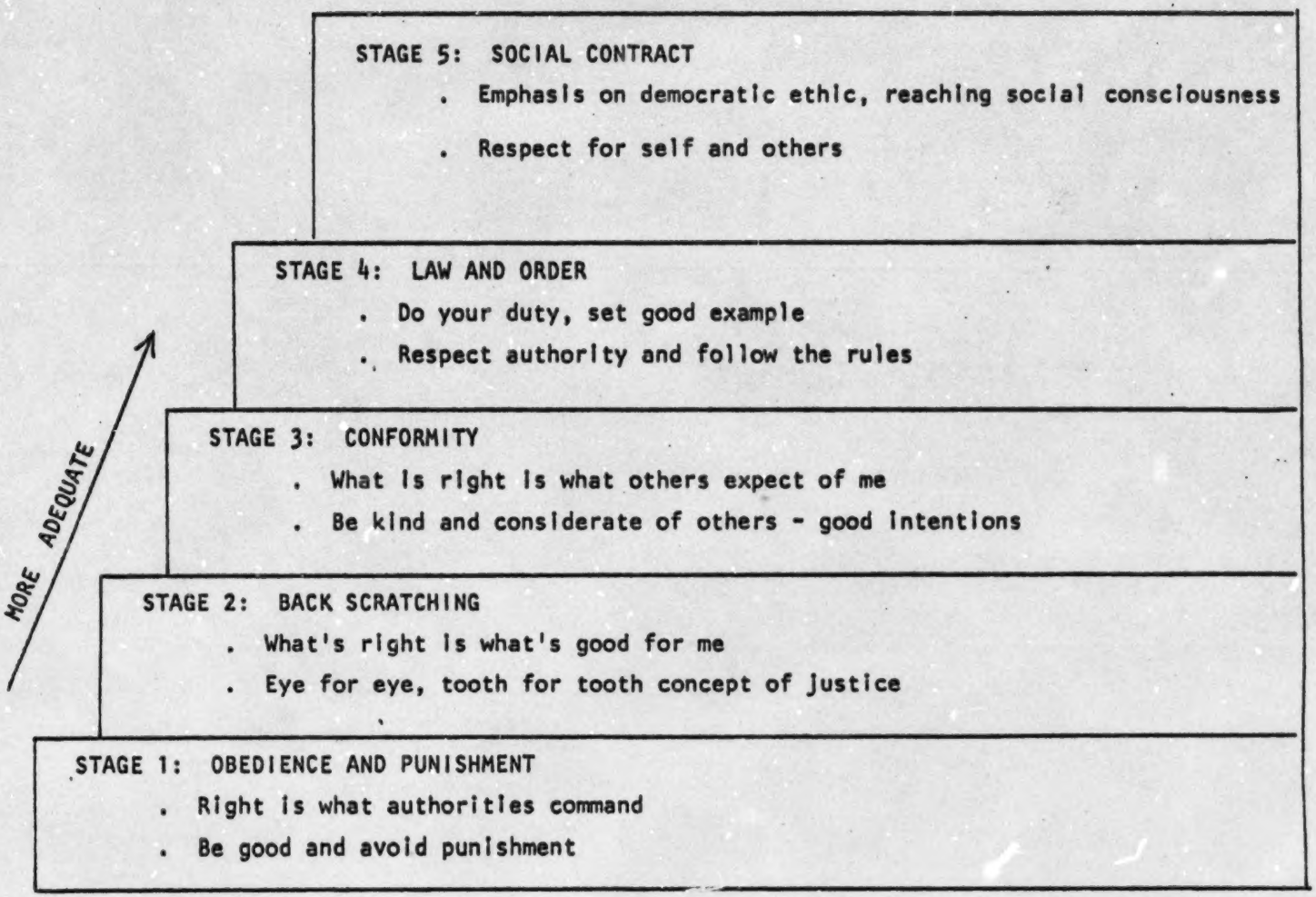
Social Role-Taking Stages

The research of Robert Selman (1976) indicates that social role taking ability is a developed capacity which also progresses in a series of stages from early childhood through adolescence. Role taking is viewed by Selman in terms of qualitative changes in the manner a child structures his understanding of the relationship between the perspectives of self and others.

Using the open-ended clinical method of inquiring first applied by Piaget

TABLE 2

KOHLBERG'S STAGES OR MORAL DEVELOPMENT


STAGE 5: SOCIAL CONTRACT
. Emphasis on democratic ethic, reaching social consciousness
. Respect for self and others
STAGE 4: LAW AND ORDER
. Do your duty, set good example
. Respect authority and follow the rules
STAGE 3: CONFORMITY
. What is right is what others expect of me
. Be kind and considerate of others - good intentions
STAGE 2: BACK SCRATCHING
. What's right is what's good for me
. Eye for eye, tooth for tooth concept of justice
STAGE 1: OBEDIENCE AND PUNISHMENT
. Right is what authorities command
. Be good and avoid punishment
MORE ADEQUATE

and then later by Kohlberg, Selman has identified and defined Stages 0 through 4 (age range is approximately 3 years to 15+ years). Descriptions of the role taking stages appear in Table 3. Each of Selman's Role Taking stages relates closely to and parallels Kohlberg's moral reasoning stages.

The social role taking stages are viewed as a link between Piaget's logical reasoning stages and Kohlberg's moral reasoning stages. Just as Piaget's logical reasoning stages are necessary but not sufficient for attaining the parallel moral reasoning stages, a similar necessary but not sufficient relationship appears to exist between the social role taking stages and parallel moral reasoning stages.

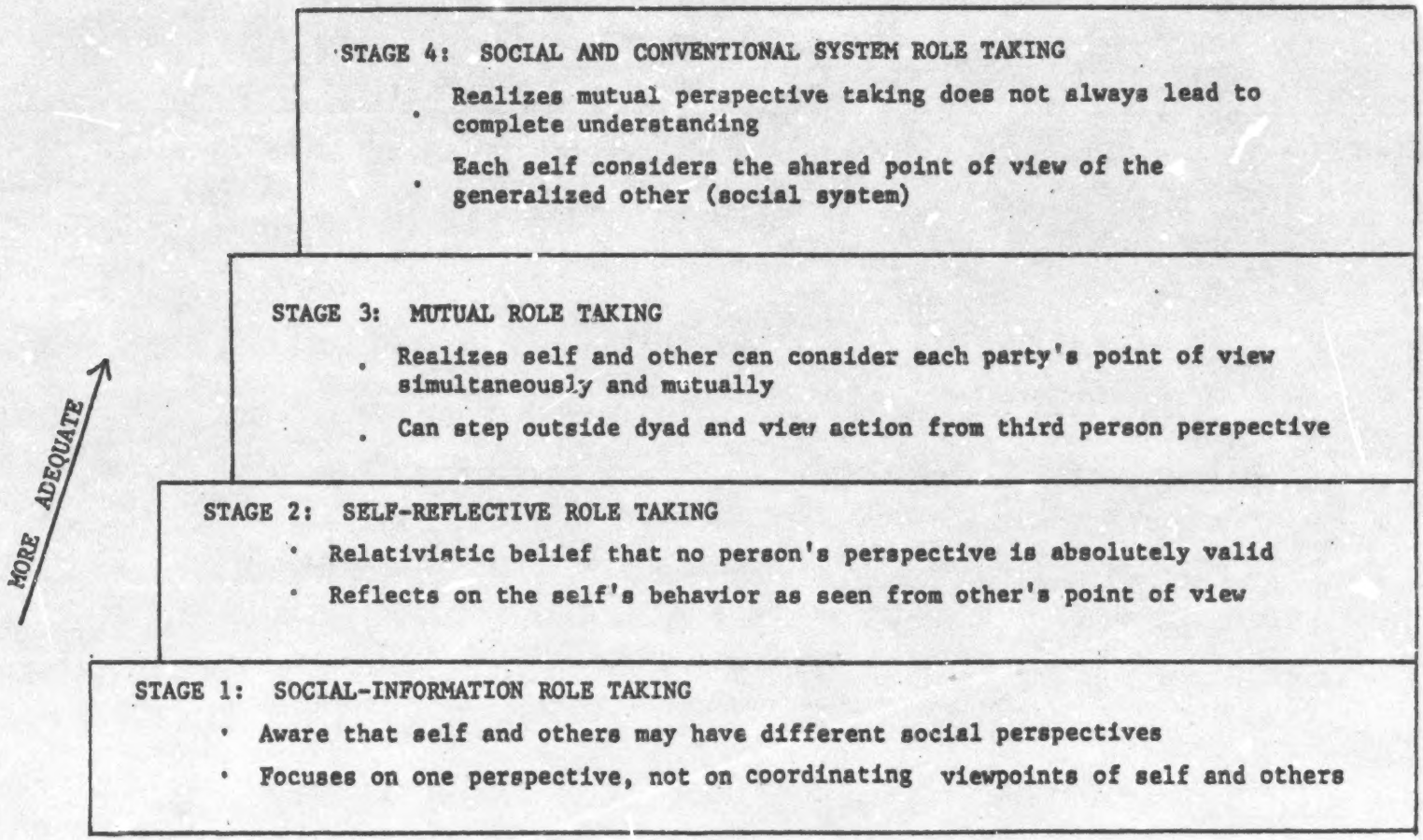
As Selman has pointed out, "...the child's cognitive stage indicates his level of understanding of physical and logical problems, while his role taking stage indicates his level of understanding of the nature of social relations, and his moral judgment stage indicates the manner in which he decides how to resolve social conflicts between people with different points of view" (1976, p. 307).

III. The Socio-Scientific Reasoning Model

Combining our own philosophy, ideas, and research with the theories of Piaget, Kohlberg and Selman, the socio-scientific reasoning model has been developed. Socio-scientific reasoning, as defined here, is the incorporation of the hypothetico-deductive mode of problem solving with the social and moral/ethical concerns of decision-making. The model has served as a guide in the development of a series of educational materials to help students advance

TABLE 3

Selman's Role-Taking Stages


STAGE 4: SOCIAL AND CONVENTIONAL SYSTEM ROLE TAKING
• Realizes mutual perspective taking does not always lead to complete understanding
• Each self considers the shared point of view of the generalized other (social system)
STAGE 3: MUTUAL ROLE TAKING
• Realizes self and other can consider each party's point of view simultaneously and mutually
• Can step outside dyad and view action from third person perspective
STAGE 2: SELF-REFLECTIVE ROLE TAKING
• Relativistic belief that no person's perspective is absolutely valid
• Reflects on the self's behavior as seen from other's point of view
STAGE 1: SOCIAL-INFORMATION ROLE TAKING
• Aware that self and others may have different social perspectives
• Focuses on one perspective, not on coordinating viewpoints of self and others
MORE ADEQUATE

to higher levels of thinking and reasoning capabilities. Moreover, it is highly flexible and readily adaptable to other curriculum development efforts.

The basic assumption of this model is that effective problem solving for the future requires simultaneous development in the realms of logical reasoning, social role taking, and moral/ethical reasoning. Purely objective scientific thinking cannot be applied in the resolution of most of the probable future conflicts without regard to the impact of those decisions on human needs and human goals. A technological solution, for example, may be, after critical analysis, feasible and logically consistent. From a societal perspective, however, one must question whether or not it should be applied. How to best prioritize our needs and evaluate trade-offs with a concern for the needs of future generations involves logical reasoning and critical thinking, but now with an added dimension...a social moral/ethical reasoning dimension.

Hence, the Socio-Scientific model consists of four interacting components (see Figure 1): (1) logical reasoning development is based on the theories of Piaget, while (2) moral/ethical reasoning relies strongly on Kohlberg's ideas. Selman's research provides the basis for the third component, the social role taking aspects of our model. Since the content or information component of the problem (component four) will vary, so too will the concepts vary accordingly. For example, in our applications of this model we have concentrated on issues at the interfaces of science, technology, and society. Of course, problem issues could also deal with or focus on any other topic one chooses to investigate.

The content component also consists of three interacting subunits. These subunits--science, technology, and society--rely on each other for their very existence. While each of the subunits is dependent upon the others, their

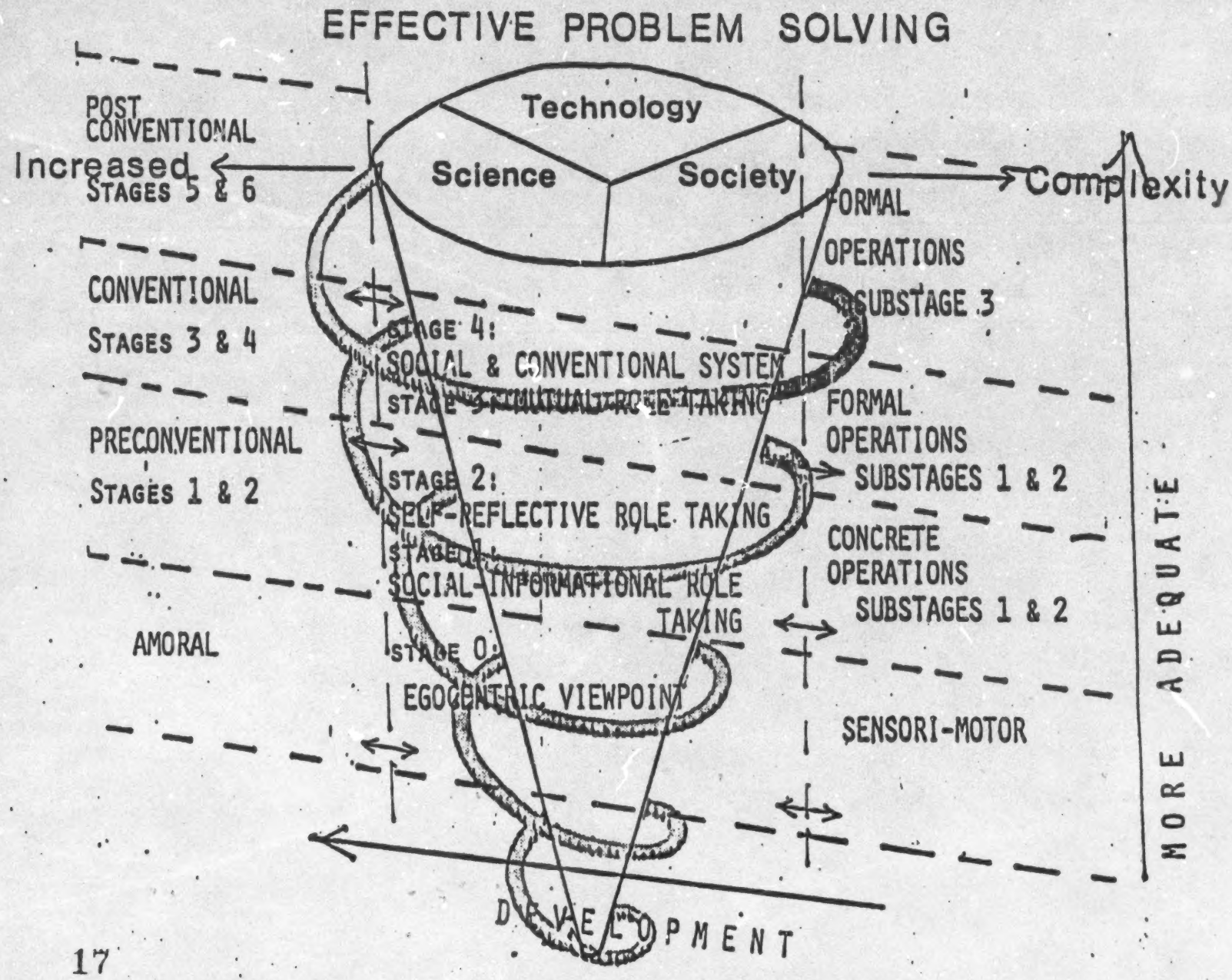


FIGURE 1
THE SOCIO-SCIENTIFIC REASONING MODEL

individual underlying value structures create a high potential for discord since the concerns of one subunit often conflict with those of the others. This paradox--dependence and simultaneous conflict among the subunits--presents a unique opportunity and context for curriculum developers employing the Socio-Scientific Reasoning model to prepare future focused educational materials.

Each component of this model is not seen as a totally separate and distinct entity. Rather, each of the four components interacts with and has an effect on all other components. Thus, logical reasoning has an effect on, and in turn is affected by, social role taking development. In a similar manner, social role taking has an effect on, and is affected by, developments in the moral/ethical realm. Of course, logical reasoning and moral/ethical reasoning also interact. Each of these major components--logical reasoning, social role taking, and moral/ethical reasoning--interact not only with each other but with the fourth component, content or information.

Referring to Figure 1 again, the content cone is small at the low end because at earlier stages of development the number of concepts entertained are smaller and the concepts are simple in nature. Hence, as the cone broadens so too does the complexity of content or information included. Individuals at stages of development intersecting the lower end of the cone can deal with issues and concepts of a simpler form while, on the other hand, individuals at the upper end with higher levels of maturity have the capacity for dealing with more issues and issues of greater complexity. Development, then, is both vertical and horizontal: vertical development is from lower to higher stages; horizontal development relates to the "necessary but not sufficient" requirements which must be satisfied as one moves from logical reasoning, through social role taking, to moral reasoning capabilities.

Thus, while each stage reflects a distinctly unique capability for problem solving in a science/technology/society context, we view development or progress as a continuously spiraling process. In this process, however, there are leaps and quiesence, and fixation at any stage is possible. Levels of logical reasoning, moral reasoning, and role taking maturity also seem to vary, we find, depending on the issues addressed. These apparent inconsistencies in reasoning--even when dealing with the same or similar mental and moral constructs--seem to be related to the degree of emotionality, familiarity with, interest in, and/or knowledge about the issues under consideration (Iozzi, 1976).

The goal then is to help each individual "spiral" upwards through the Socio-Scientific Reasoning cone and synchronously achieve "more adequate" problem solving capability. "More adequate" as used here refers to the idea that when applied to problem solving, the higher stages of reasoning result in solutions that are more encompassing and generalizable; they enable students to deal with greater complexity.

IV. Applying the Socio-Scientific Reasoning Model

The application of our socio-scientific reasoning model centers on identifying those learning experiences important for assisting students to become more effective and capable decision-makers and problem solvers in a highly scientific and technological world. This model should also prove to be useful in helping curriculum developers determine the types and complexity of activities appropriate for students at different grade levels, with differing abilities, and with differing learning needs and requirements. Implicit in the model and in accord with stage theory is the idea that at each stage there is a characteristic form of thinking capability which determines how

experiences and information are interpreted and acted upon.

The main strategy underlying all of these activities is based on Piaget's concept of equilibration. It is only when disequilibrium is created that active restructuring of thought takes place. This active restructuring leads to growth in logical reasoning and, we contend, growth in social role taking and in moral/ethical reasoning capabilities as well.

Restructuring of existing cognitive structures occurs when internal disequilibrium is felt by the individual. New experiences and inputs which are not readily comprehensible to the individual challenge his/her existing mode of thought by revealing inadequacies or inconsistencies in that problem solving strategy (Tomlinson-Keasey, 1974). Arrestment at a given stage is partially explained by the developmental theorists as the lack of opportunities that create conflict or dissonance which place the individual in a position where he/she needs to assess his/her particular mode of thinking. Perhaps, as Clive Beck points out, the reason why people do not develop morally is because they have not had the opportunity to entertain alternatives--their imaginations have not been extended (1972). We, in addition, contend that the reason people do not advance in logical reasoning can also be attributed, to a large degree, to a similar lack of opportunities.

We have identified some of the basic elements needed to provide experiential opportunities that promote development of problem solving and decision making skills. One educational activity which incorporates some of these elements is the classroom dilemma discussion, an activity most commonly associated with Lawrence Kohlberg and his colleagues. We have, however, modified and extended this approach to more systematically encompass critical analysis and evaluation of information and data. We have also employed such other formats as role taking, simulations, and futures forecasting and analysis methodologies.

Effective discussion, however, cannot take place in a vacuum. Needed also is an information base or context from which students can begin to analyze and evaluate information. With information which they have extracted and synthesized, additional ideas and rational arguments can be developed for discussion. For curriculum materials, we have created problem situations in a variety of contexts which, according to scholars in a variety of fields, will be prominent in the next quarter century and beyond (Shane, 1977). This adds another perspective to the dilemma problem--that which elicits scientific logical reasoning in addition to moral/ethical reasoning--but in a futuristic context.

Included in each curriculum module are several types of extension activities. These serve as mechanisms for students to put some of the ideas and judgments that have emanated from the discussion into larger structural frameworks. They also provide students with opportunities to project into the future, to think beyond their own immediates experiences, and to consider the impact of different decisions on future society.

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